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SPACE INFRARED TELESCOPE FACILITY
WIDE FIELD AND DIFFRACTION LIMITED ARRAY CAMERA
(IRAC)

Grant NAG 2-316

Semiannual Status Report No. 4

For the period 1 March 1986 through 31 August 1986

Principal Investigator

Dr. Giovanni G. Fazio

October 1986

Prepared for
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California 94035

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is Mr. Ruben Ramos, Mail Code
244-15, National Aeronautics and Space Administration - Ames Research
Center, Moffett Field, California 94035

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SPACE INFRARED TELESCOPE FACILITY
WIDE FIELD AND DIFFRACTION LIMITED INFRARED ARRAY CAMERA
(IRAC)

Smithsonian Astrophysical Observatory
Goddard Space Flight Center
Ames Research Center
University of Arizona
University of Rochester

SEMIANNUAL STATUS REPORT
for the period
1 March 1986 through 31 August 1986
Grant NAG 2-316

1.0 SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

Effort during the reporting period focused primarily upon development of IRAC focal plane detector technology and on supporting studies of alternate focal plane configurations for the Ned Wright Committee. While any of the alternate focal planes under consideration would have a major impact on the Infrared Array Camera, it has been possible to proceed with detector development and optical analysis research based on the proposed design since, to a large degree, the studies we have undertaken are generic to any SIRTf imaging instrument. Development of the proposed instrument was also important to assure timely development of the conceptual design of the instrument in a situation in which none of the alternate configurations had received the approval of the Science Working Group. We also supported other Science Working Group activity, Mission Operations Sub-Group activity, Detector Sub-Group activity, and continued analysis of the IRAC optical system. This report summarizes the status of these efforts at the end of August 1986.

1.1 Science Working Group Activity

Dr. Fazio attended the SWG Meetings at Ames Research Center March 10 - 13, 1986 and August 12 - 14, 1986. Dr. Pipher also attended the August Meeting. Specific topics considered during the March meeting included review of the SIRTF reference concept and descoped concept, review of the FY86 technology development program and evaluation of IRAC instrument descope options. A fresh look was taken at the scientific objectives of the IRAC program with an eye towards identifying possible instrument simplifications. The August meeting focused heavily on consideration of alternate focal planes. The impact of the favored strawman instrument on the Infrared Array Camera is discussed in the section covering activities of the Ned Wright Committee.

1.1.1 Ned Wright Committee Activity -

Support of the activities of this committee proved to be a major effort during this period. The impact of descoping the performance of the facility on the scientific objectives of the IRAC program were considered and a search was made for simplifications to the instrument which might result therefrom. Various alternate focal plane configurations were also considered. The proposed strawman IRAC focal plane would increase array size in Bands II and III to 128 X 128 to provide diffraction limited performance down to 10 microns without a magnification change mechanism and add a 32 X 32 array longward of 60 microns. As this is written, no firm decision has been made on focal plane changes and we are proceeding with development of the original instrument concept until such time as an agreement is reached. The proposed strawman concept does not allow for

diffraction limited performance in Band I and compromises IRAC scientific objectives. Further, at 128 X 128 pixels in all three bands we would double the number of arrays presently planned for IRAC with severe cryogenic power dissipation and cost impacts.

1.1.2 Detector Sub-Group Activity -

SAO took part in the Detector Telecon May 10, 1986 which reviewed detector development status and planned follow-on effort. There was no other Detector Sub-Group activity.

1.1.3 Mission Operations Sub-Group Activity -

Dr. Gary Melnick represented the IRAC Team at the meeting at Ames in August. We reviewed the Mission Operations Center concept and plans for common computer purchases presented at the meeting and provided comments to Fred Witteborn by telephone soon afterwards.

1.2 IRAC Team Meeting Activity

There were no formal team meetings held during the reporting period. The next formal Team Meeting is scheduled for October 23 and 24, 1986 at SAO.

1.3 Program Management and Planning Activity

1.3.1 Progress Against Plan -

The technology development flow chart is given in Figure 1. Effort has proceeded as planned although at a somewhat slower pace due primarily to slower than planned deliveries of detectors in all three bands and to detector test facility noise problems. As this report is written Band I effort is about five months behind plan due primarily to late InSb array delivery. The regular InSb array has been delayed due to an array processing problem at SBRC of as yet unknown origin which leads to unexpectedly low responsivity at the expected operating temperatures. SBRC has a research program underway to identify the cause for this unexpected result (earlier regular InSb arrays performed as expected) and SAO is tracking their progress since the processing problem could conceivably affect later SIRTF production runs. The present SIRTF detectors show no signs of this anomalous behavior.

In Band II, all milestones except the spatial resolution test have been completed and those tests are expected to be done in November 1986. The second Band II Si:Ga array, purchased outside the SIRTF program but available for us to test, has been successfully fabricated by SBRC and is expected to be delivered in November 1986. GSFC/697 Bit Slice Processor and dewar construction is virtually complete and will be ready for debugging and initial tests with the new array in December 1986.

Band III tests have also been delayed by late array deliveries although ARC now has received all its arrays and the test program is underway.

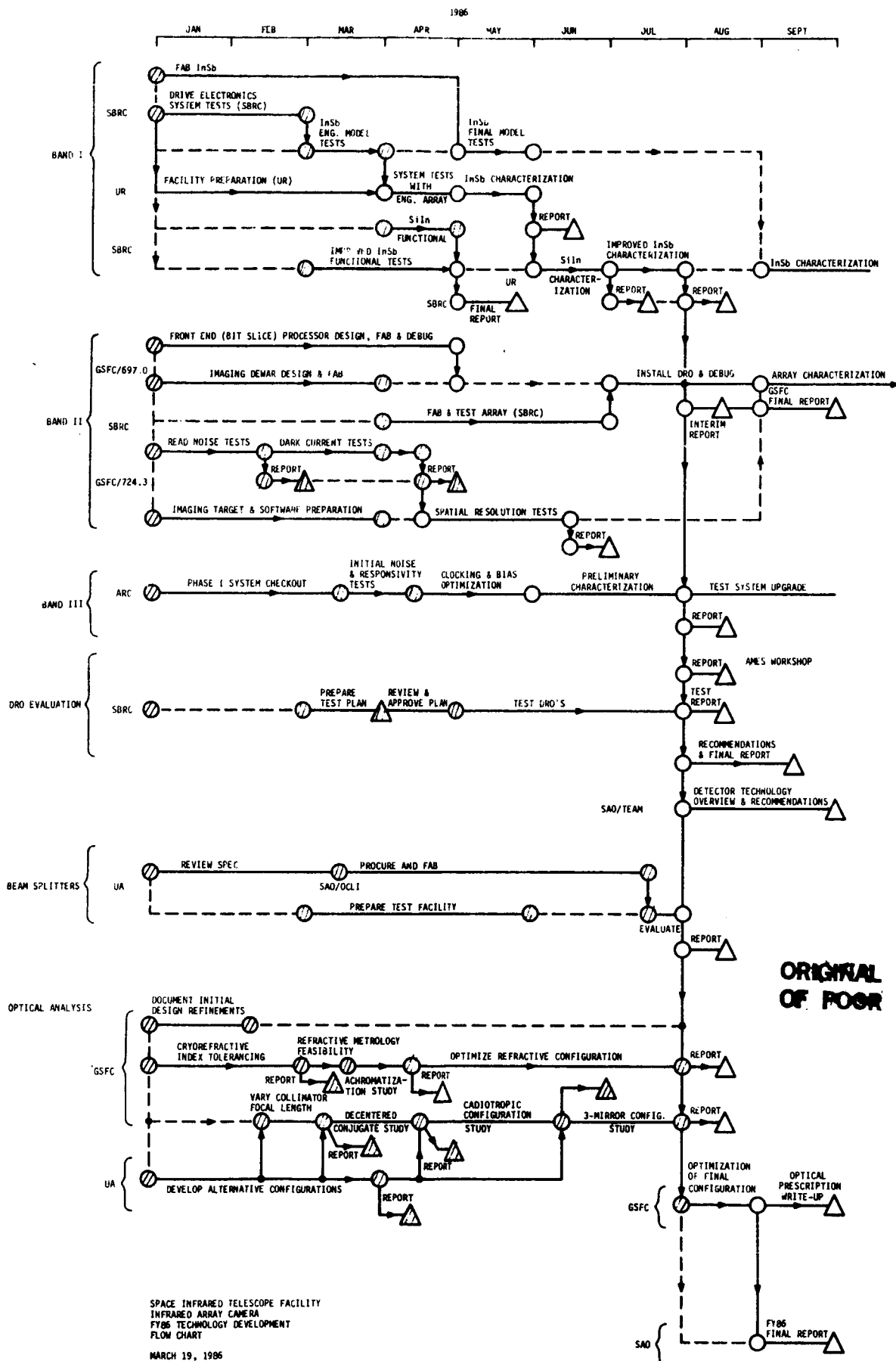


Figure 1. FY86 Technology Development Flow Chart

The test sample beam splitters were delivered to SAO in August 1986 and subsequently sent to Arizona for evaluation. The test facility is ready and testing will be underway in October 1986.

Optical design effort at GSFC has been completed on schedule and a final report is in preparation. A preliminary report has been issued as IRAC-402.

Further details on all of these activities are presented in the technical activity descriptions below.

1.3.2 Program Coordination -

The Team met weekly via telecon during the period. These telecons focused on program planning and coordination, scientific planning and discussion of technology issues. These telecons were the primary means of coordination among the Team during the period and have proved to be highly effective. They run about a hour generally and we usually have participation by the majority of the Team. This approach allows us to quickly redirect the team when required and to address technical issues in a timely fashion as they arise.

1.3.3 GSFC Technical and Programmatic Reviews -

Reviews were held monthly at GSFC throughout the period. Technical reviews are held in the morning among IRAC Team members only and programmatic reviews in the afternoon among the IRAC Team and GSFC management. The technical reviews were working meetings which included program redirection as required. Morning meetings were generally attended by the Goddard Co-Investigators, SSC Members, and the IRAC Instrument Manager as well as SAO personnel.

Mr. Jimmy Cooley joined the IRAC Team as Instrument Manager early in May and, beginning with the May review, was responsible for developing and coordinating the meetings. He has developed a standard presentation format for technical, financial and schedule status based on the successful format used on the Galileo program. This format will also be the basis for GSFC Definition Phase reporting. Technical, financial and schedule status is presented against the baseline plan in a manner which allows straightforward evaluation of program status. The September 1986 meeting report is attached to this semiannual report as Appendix A as an example of the report format.

The status of the GSFC effort is presented in the technical discussion sections which follow.

1.3.4 SBRC Technical and Programmatic Reviews -

SBRC performance during the period ran considerably behind the initial schedule due to fabrication problems with the array detectors and test set interference with other SBRC programs. These problems were dealt with successfully in June when a new SBRC Program Manager with strong array technical background was appointed following a detailed SAO management review. Technical progress through the end of August has been satisfactory although program delays continue to be experienced as a result of test set scheduling conflicts. As this report is written, SBRC has a set of three InSb arrays available for characterization and delivery of the SAO array is expected in November 1986. The Si:In array also deliverable under this contract is complete and available at SBRC.

As a result of the testing performed to date, at least one of the InSb arrays is known to perform successfully at SIRTF operating temperatures and is demonstrating read noise performance of about one-half of the level measured on the standard InSb product. This was one of the expected benefits of using low-doped InSb in the detectors and means a major goal of the development effort has been met. Unfortunately noise performance of the array is still short of SIRTF goals and the importance of follow-on DRO development effort in understanding the theoretical and practical performance limits of Source Follower Device DRO's, like the CRC-228, has been re-emphasized.

Additional information on the status of this effort is provided in the SBRC status section below. As a result the delays experienced in the InSb program, we now expect that it will be necessary to extend the grant period of performance through March 1987 to allow completion of the DRO test and

evaluation effort planned as a follow-on activity.

1.3.5 Instrument Requirements Document -

A strawman Instrument Requirements Document (IRD) was completed by GSEC during the period and, at the time of this report, has been rewritten into a draft IRD and circulated to the Team for review by SAO. The IRD includes specific design and performance requirements for the Infrared Array Camera and has been issued as document IRAC-202.

1.3.6 Documentation Status -

A series of numbered IRAC Memos has been created to maintain critical technical analyses and discussions in an easily accessible form throughout the program. A list of these memos will be maintained by the SAO IRAC Project Office and will be updated and released regularly.

An up-to-date list of IRAC documents and memos is attached to this report as Appendix B.

1.3.7 Letter of Agreement -

The Letter of Agreement under which the IRAC program will be managed was signed by all parties and made effective 1 August 1986. A copy of the signed LOA was sent to the SIRTF Program Office on October 3, 1986.

1.3.8 Submission of Revised Definition Phase Proposal -

Request for Proposal RFP2-31769/Rev. 1 (LAK) was received by SAO on June 4, 1986 and a revised Definition Phase proposal P1376-11-83 Rev.4 submitted on July 14, 1986. By separate request of the SIRTF Program Office an alternate cost proposal was included as Appendix G to Volume III, the Cost Proposal. A number of exceptions were taken by SAO to specific DR and contractual requirements. As this report is prepared, most of these exceptions have been negotiated with the SIRTF Program Office and all additional information requested has been provided. SAO is ready to negotiate the contract with Ames and expects a November 1986 start date for the effort.

1.4 University of Rochester - Band I Effort (Insb & Si:In Arrays)

During this period, the University of Rochester has taken delivery of the SBRC FPADIE and FPACIE electronics packages (March 1986, re-delivered) as well as the engineering Insb DRO array (May 1986). The card cage in one of the two electronics boxes as well as certain wires were damaged in shipment the first time it was delivered; these were replaced and/or fixed by SBRC at the beginning of this reporting period. In addition, we have taken delivery of the DFC DRV11J parallel interface, as well as two 16-bit Data Translation DT2757 A/D converters. Since that time, considerable effort has been expended in interfacing the electronics, and systematically ironing out the electronic problems and errors in the deliverables that we have encountered. A summary of this, and related activity, is detailed below.

The first step was to build an interface box from the SBRC electronics to the parallel interface in our dedicated LSI 11/73 computer. Software to operate this was developed (in FORTH, the programming language we employ). As the noise testing program proceeded, we discovered that after the SBRC electronics were re-delivered, there were the following problems:

- we located 5 bad chips, and 1 bad resistor
- there was faulty wiring on one card (ground bridge missing: added extra noise)
- there were 2 pin connections missed on a chip at the design level; i.e. all the SBRC delivered electronics had this problem
- the offset trim introduced 'pistoning' in the output; we rewired the card, and reduced noise by factor of 6
- more subtly, our questions to SBRC have introduced additions to the manual revision #2 (for example, the RFD request for data pulse is a function of readout rate: this information now specified)
- the -15V supply on the FPACIE doesn't always turn on; this hasn't been yet resolved.

The most recent problems with the SBRC electronics have been discovered once we interfaced with the two preamps we built (x5 followed by x10) located inside our dewar; originally it appeared that there was high noise associated with the preamps. We originally suspected the op amps. However, it turned out that the A/D had a broader bandwidth than believed, and when a special filter was constructed to limit the bandwidth, the

pre-amp noise met specifications. Since the SBRC electronics limits the bandwidth, the output of the preamps to the SBRC did not require this filter. However, the SBRC anti-aliasing filter introduced different noise levels (by a factor of 2) at different readout rates. Read rates of 2, 8, and 32 microsec were high noise, and 4, 16, 64 microsec low noise. A filter on our x10 preamp with identical bandwidth characteristics to that in the SBRC electronics minimized the high noise values by a factor of 1.5, while raising the low noise values slightly. These problems highlight the fact that the signal processing boards are not working perfectly. SBRC has indicated that a redesigned card will become available. We are presently trying a differential input to one of the op amps on the SBRC signal conditioning board, to further improve the noise. Presently the system noise, including the preamps, is between 4 and 15 ADU rms, or 64 to 240 electrons. This is useable, but we are attacking these last noise problems before cool down of the array.

During this same period, we rewired an old observing dewar for this program. Unfortunately, the dewar developed a major leak on the cold surface interface. We attempted to fix this: until our new dewar (ordered from Electromechanical Designs) is delivered (end of September) we plan to operate the old dewar with a half-inch of frozen water to seal the leak. During our attempts to seal the dewar, the wiring and fan-out board developed high impedance shorts: eventually major surgery was necessary, and all is now functioning correctly.

In addition, there were problems with the A/D boards as delivered. Originally they had a noise figure of 1.8 ADU; after they reconfigured it by changing op amps and bandwidths, the noise is 0.8 ADU. Also they suffered from 'sticking' at particular conversion values, a problem which

they have also rectified. The first one was sent back twice; our second board has still not been finally delivered with these changes. Data Translation is now making these changes 'standard' on their boards.

The software for running the DRO is being written. Most of the basic words exist, and the ability to read and write from disk implemented. These programs are partially an adaption of techniques used to run our CCD, and employ the extended memory capability developed previously for our image processing.

We have been in frequent contact with SBRC, and have participated in monthly meetings there as the problems with the InSb technology, and DRO technology have been addressed.

1.5 Santa Barbara Research Center - Band I Effort ("Improved Insb and Si:In Arrays")

Program status at the end of August 1986 is as follows:

1. Six SCA's* and Six HDA's** have been fabricated since July.
2. SCA SFA002 has excellent operability and radiometric performance at 8 Kelvin.
3. SCA SFA002 leakage current measured to be $< 1\text{fA}$ at 8 Kelvin.

* Sensor Chip Assemblies,

** Hybrid Detector Assemblies. An SCA is an assembly of a detector board and a Direct Read Out (DRO) chip. The DRO provides random access to all detectors on the detector board. An HDA is an assembly of a detector board and a fan out board which provides direct access to about a dozen individual detectors on the detector board.

4. Detector gate shorts have developed in HDA's tested during either fabrication or test.

The measured dark current is about far too high for IRAC use which has a design goal of < 0.01 fA. Dark Current vs. Temperature for this array is shown in Figure 2 and its distribution at 10 Kelvin in Figure 3. A minimum of 0.587 fA is reached at 10 Kelvin. We believe that the dark current measurement is instrumentally limited. Dark current will be remeasured at Rochester as a part of the array characterization program.

One of the primary goals of the Improved InSb program was to reduce detector capacitance through the use of low doped InSb. The capacitance of SFA002 was measured dynamically under the conditions shown in Figure 4 to be 0.53 pF, or almost exactly half the detector capacitance of the standard InSb arrays. Therefore one of the major goals of the Improved InSb program has been met.

The reason for seeking lower detector capacitance is to lower read noise. Read noise with this array was found to be 355 electrons/read at 5.8×10^7 photons/cm²-sec. This is about half of the present read noise of the standard InSb product, demonstrating again the advantage of the lower detector capacitance, but still too high for the IRAC camera. Since we initially projected a read noise in the 150 electron range for this array based on the earliest standard InSb estimates, additional work must be done to establish a theoretical basis for this result and to determine the viability of the source follower type of DRO for IRAC.

Figures 5 and 6 give the quantum efficiency (QE) and NEP for this device and display its linearity as a function of photon flux. The quantum efficiency is lower than expected at 44% (the specification was 60%).

Dark Current vs. Temperature

SFA-2



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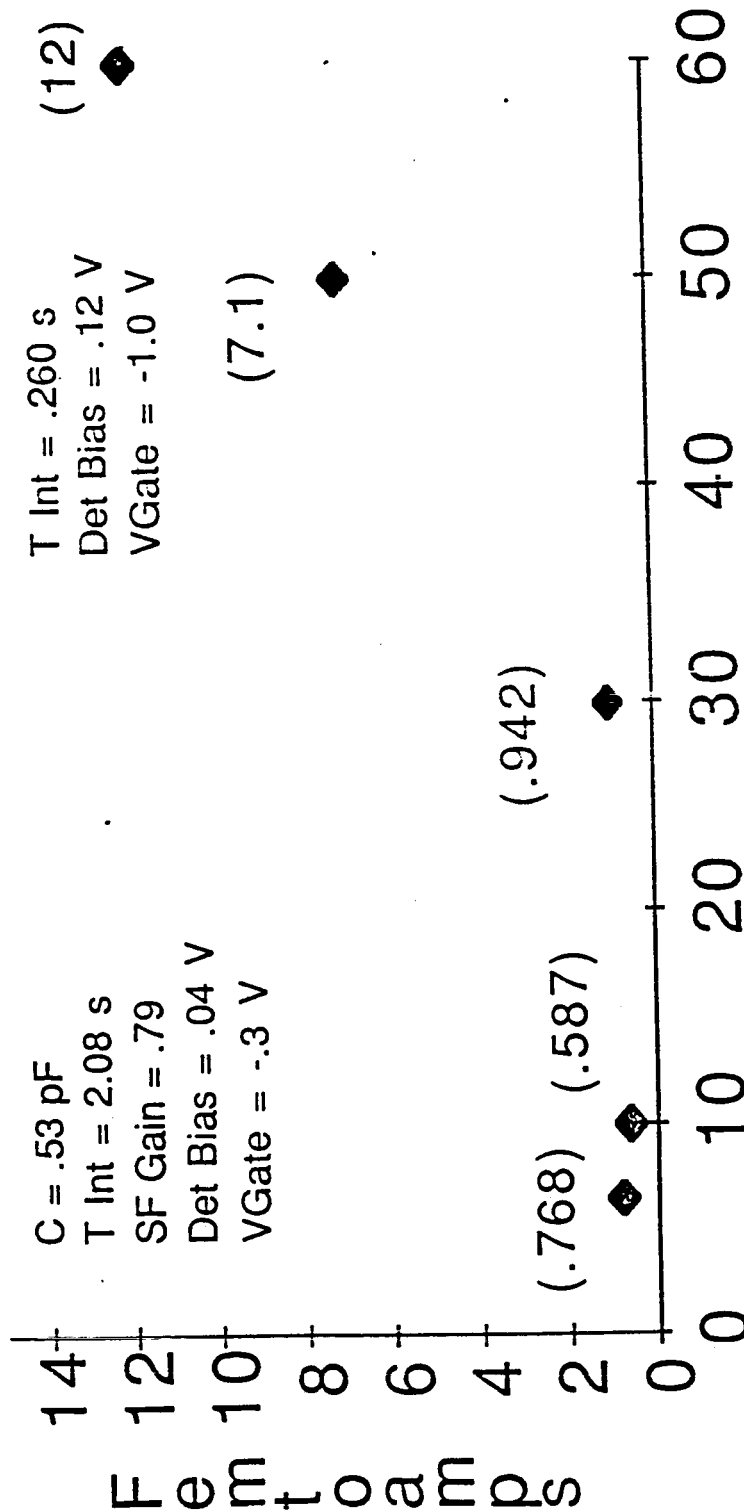


Figure 2. Dark Current vs. Temperature

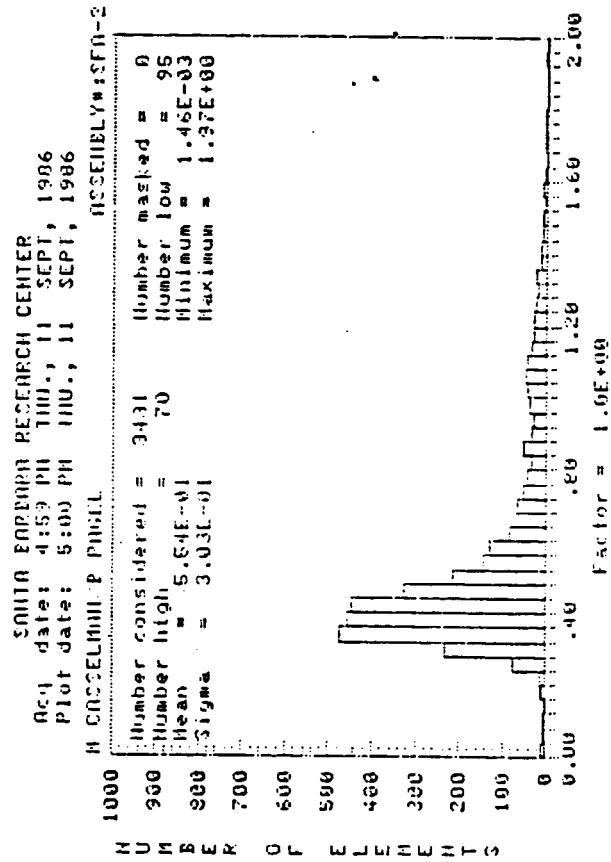
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DARK CURRENT MEASUREMENT AND DATA FOR FOCAL PLANE ARRAY NO. SFA-2



SOUTH ENDORPH RESEARCH CENTER
II SUBSTATION

TEMPERATURE: 10 K



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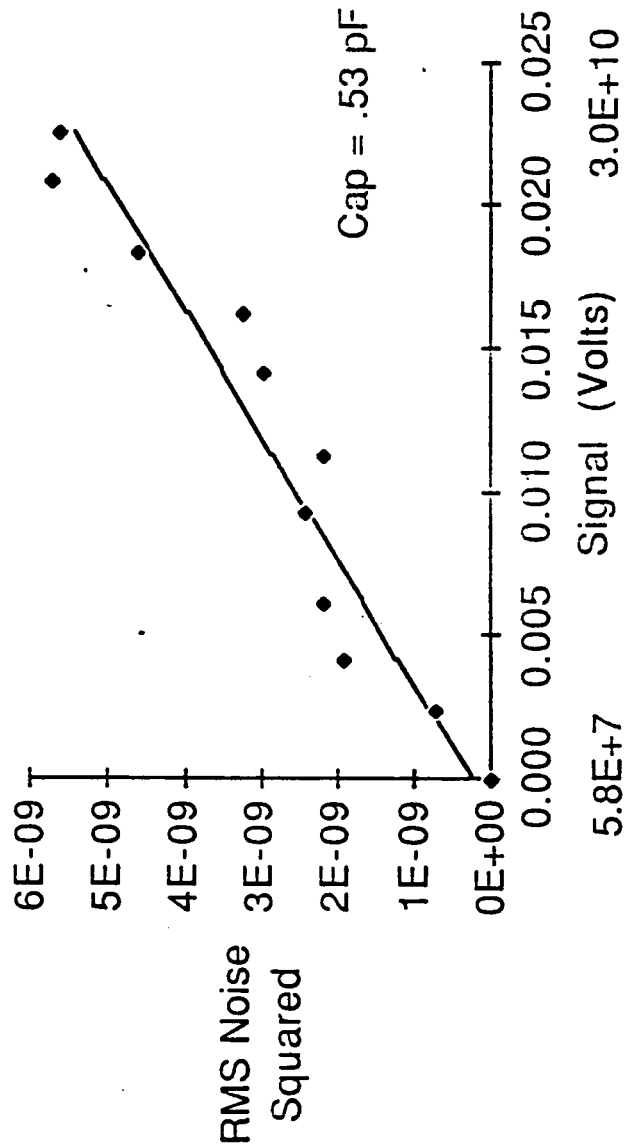
Figure 3. Dark Current Measurement and Data for Focal Plane Array No. SFA-2

CAPACITANCE MEASUREMENT



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SFA-2



Bias = .04 V
Gate = -.3 V
Qbg = 5.8 E+7
WL = 2.35 μ m
Tint = .130 s
T = 8 Kelvin

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Figure 4. Capacitance Measurement

RADIOMETRIC PERFORMANCE

8 KELVIN



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NEP = 2.9×10^{-16} Watts at 5.8×10^7 photons/cm²-sec Background

Corresponding D* is 3.5×10^{13} cm-Hz^{1/2}/Watt

NEP = 3.42×10^{-16} Watts at 9.4×10^9 photons/cm²-sec Background

Corresponding D* is 2.9×10^{13} cm-Hz^{1/2}/Watt

D*BLIP is 8.6×10^{13} cm-Hz^{1/2}/Watt

Photo-efficiency = 0.58

Quantum Eff. = 44% calculated from signal measurements.

Noise = 355 electrons with 5.8×10^7 photons/cm²-sec

Figure 5. Radiometric Performance

SFA-2 Linearity



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C = .53 pF
T BB = 400 Kelvins
T Int = .260 s
Det Area = $6.5E-5 \text{ cm}^2$
SF Gain = .79

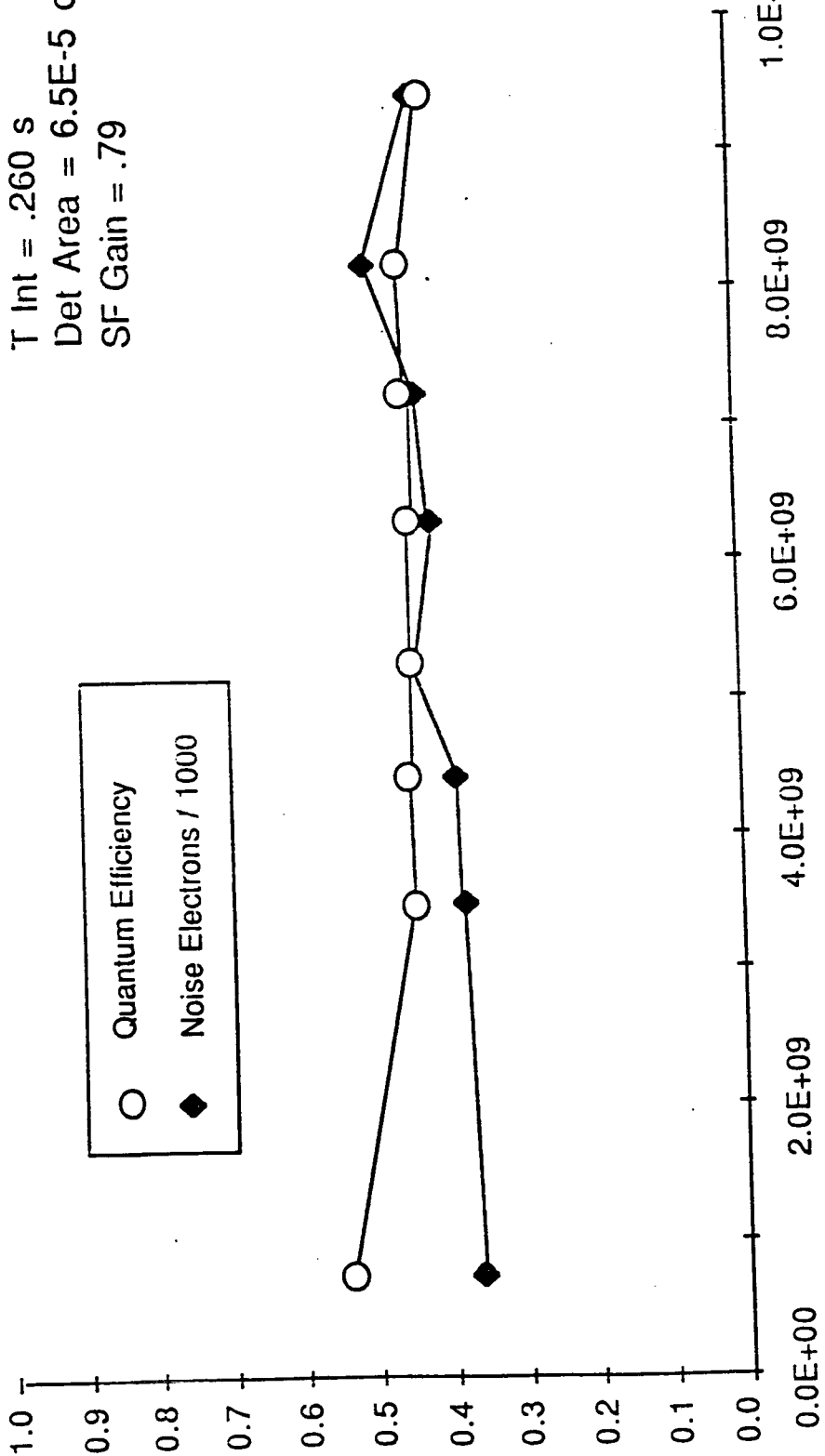


Figure 6. SFA-2 Linearity

Additional tests are planned at Rochester to remeasure QE, as well. Signal and Noise as a function of temperature are shown in Figure 7.

These results are encouraging but must be considered preliminary in light of the potential instrumental limitation on dark current and a desire to reconfirm the capacitance measurement by an independent technique.

The schedule for completion of this effort is shown in Figure 8.

1.6 Goddard Space Flight Center - Band II Effort (Si:Ga Arrays) and Optical Design

1.6.1 Summary -

The SIRTF/IRAC program for FY86, consisted of:

1. The evaluation and testing of the Band II gallium doped silicon DRO sample array detector by Code 724 personnel, under the direction of G. Lamb. The principal areas of study were read noise level, dark current, and image resolution. A report was prepared describing the read noise and dark current tests and results. The investigations of the array imaging was not completed and is proposed for FY87 work.
2. The establishment of a laboratory R and D program by the Co-Investigators (under the direction of D. Gezari, Code 697) for the purpose of characterizing the SIRTF/IRAC array detector technology in an astrophysics context. The Code 697 SIRTF array camera lab facility has been expanded and is operational; plus the design and fabrication of detector test hardware (dewar, electronics, etc.) is progressing well.



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SCA #2 SIGNAL and NOISE vs TEMPERATURE

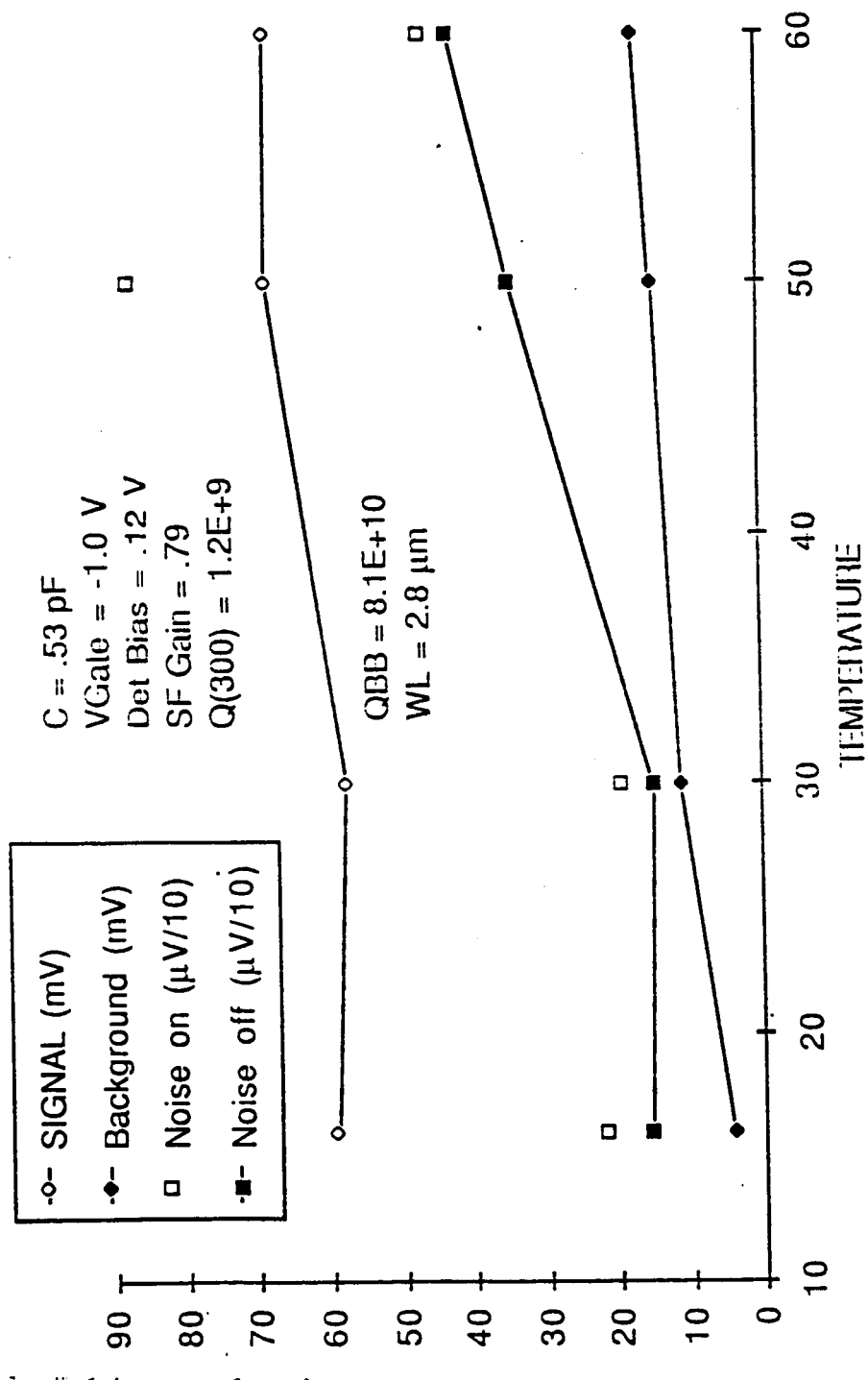


Figure 7. SCA #2 Signal and Noise vs. Temperature

SCHEDULE FOR SIRTf

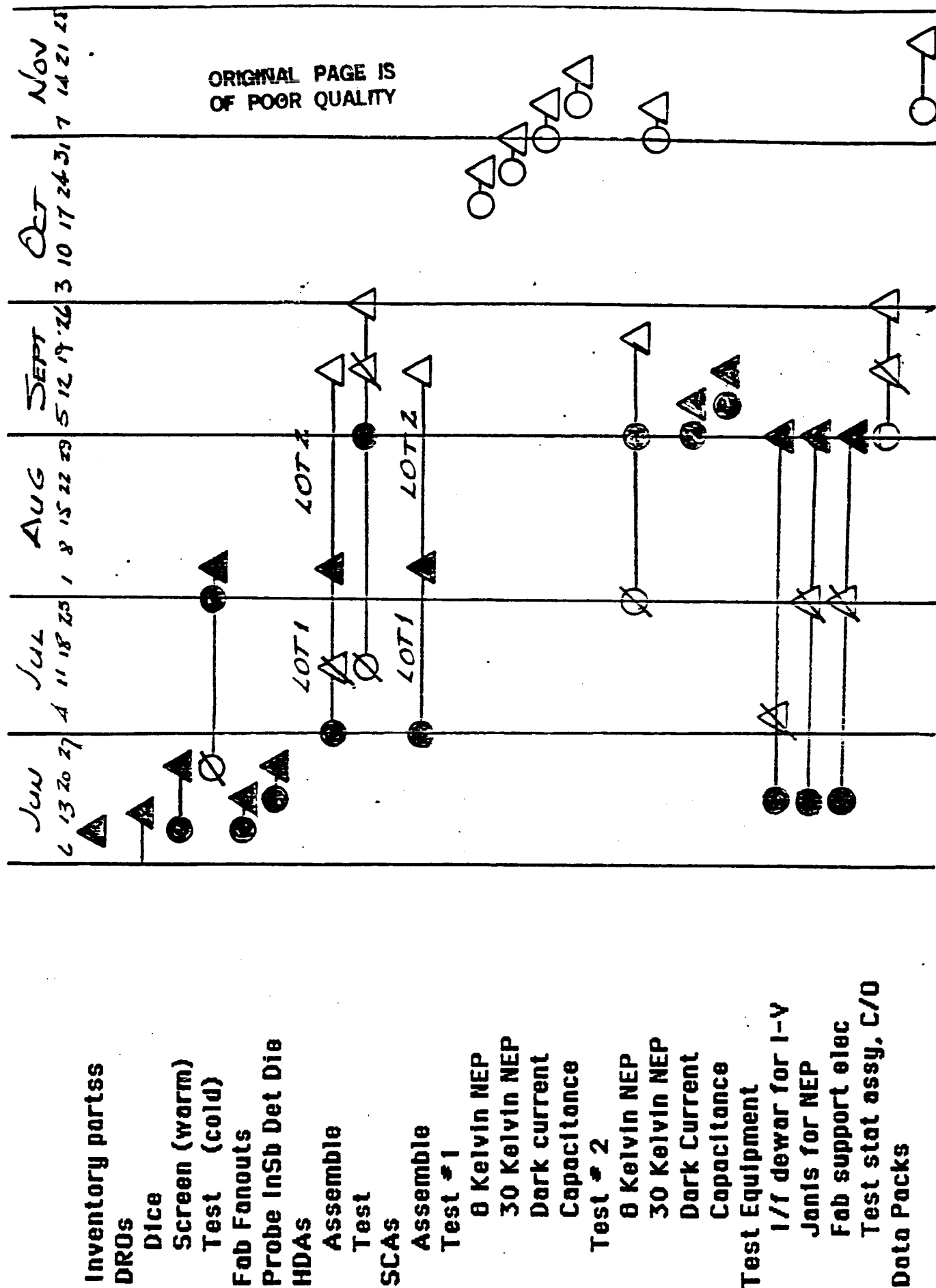


Figure 8. Schedule for SIRTf

3. The performance of optical design studies, including refractive, reflective, and catadioptric configurations on the IRAC instrument optic system by Code 717 personnel, under the direction of P. Maymon. Based on the studies performed thus far, the three-mirror off-axis unobscured reflective design is recommended. Five interim reports have been prepared by Code 717 describing the overall optical studies. These reports have been compiled into a single document "FY86 Optical Design Activity at Goddard Space Flight Center" issued as IRAC-402.

1.6.2 Band II Detector Test Program (Code 724) -

The SIRTF/IRAC Band II detector test and evaluation involved a technology assessment of a Gallium doped Silicon prototype array furnished by Santa Barbara Research Center to GSFC for study purposes.

This technology is new and as such there was a learning and development program occurring coincident with the detector evaluation program. The FY86 effort was to investigate the performance limiting behavior of the array. The device performance has been divided into three principal categories: Read Noise, Dark Current and Imaging.

1.6.2.1 Read Noise -

The read noise is a measure of the device and system electronic noise floor. The measured noise at a focal plane temperature of 5.4 degrees Kelvin and with the detector electric field intensity set to zero gave the following results:

Warm pre-Amp & Systems	127 - 164 e rms
DRO NMOS Transistors	123 - 214 e rms
Full Array	256 - 424 e rms

The read noise vs. focal plane temperature, integration time, and background photoflux tests were performed to study low background and low temperature noise.

1.6.2.2 Dark Current Test -

Extensive data was taken of the DRO dark current. This test involved the operation of the array under varying integration times and focal plane temperatures. The background radiation was minimized by foil tape over all penetrations of the liquid helium can. The background inferred by an internal Naval Ocean System Center calibrated detector was several orders of magnitude below the lowest calibrated point of $2E9$ p/s cm^2 . The tests were performed at the point where the integration capability of the array allowed clearly identified fluxes in the 400 e-/sec range per pixel. This translates to a flux of 736 p/s cm^2 . At the baseline temperature of 5.7 degrees Kelvin the average of dark currents measured was 318 e-/sec with a standard deviation of 177 e-/sec. The response was linear in integration time with the magnitude doubling for a 2X increase in integration time.

1.6.2.3 Maximum Integration Time -

The maximum integration time inferred by the dark current test results gave the array a dark current saturation in about 6000 seconds. This is considerably in excess of the expected 1000 second SIRTf maximum source integration time for an observation. Operation of the array slower than once per second is limited by baseline shift and baseline correction techniques must be applied.

1.6.2.4 Crude Imaging -

The necessary hardware and software are in place for the crude imaging tests. This includes the image acquisition software and image data reduction software. All hardware modifications are in place with the exception of two problems. During the installation of a new hard disk drive the data acquisition preprocessors developed a 'bug' where data acquisition is not possible through the system and the internal reference source developed a short in the diode temperature sensor. Since there are close tolerances within the ultraminiature housing this is not a surprise. These problems are not expected to create a delay in the crude imaging tests.

1.6.2.5 Interim Report -

The Interim Report on the Si:Ga DRO performance has been completed and is in review. The crude imaging tests are planned for FY87. This will be issued as IRAC-302, "DRO Interim Test Report - Read Noise and Dark Current", by G. M. Lamb, Goddard Space Flight Center.

1.6.3 Co-Investigator For Array Detector Research Program (Code 697) -

The goal of the Infrared Astrophysics Branch (Code 697) in the SIRTF/IRAC instrument development effort in FY 86 has been to initiate a laboratory R/D program by the Co-Investigators, for the purpose of characterizing the SIRTF/IRAC array detector technology in an astrophysics context. This approach will lead to an understanding of the SIRTF/IRAC instrument, and the development of the IRAC instrument requirements for Phase I and II.

Code 697 provided the following input and support for the SIRTF/IRAC effort at GSFC in FY 86: 1) provided Instrument Scientist, as scientific leader of the instrument development program at GSFC, 2) provided Instrument Manager as manager of the instrument development effort at GSFC, 3) drafted the strawman version of the SIRTF/IRAC Instrument Requirements Document, including the technical and scientific performance requirements, and 4) supported the detector and critical component development activities in Code 700, 5) developed an array camera laboratory in Code 697 for the SIRTF effort, and obtained new space to expand the activities of the laboratory.

A custom designed Infrared Laboratories 5" liquid helium dewar is being developed to permit operation of the Band II Si:Ga DRO array detector

at high, moderate and low backgrounds, and to allow imaging of targets outside the dewar. The cold work surface was fitted with an external cold baffle box structure, and a breadboard optical mounting set-up in the dewar has been fabricated which uses off-axis reflective optics and provides a cold aperture stop, cold filters, and baffling for the suppression of thermal background radiation. Optical ray-tracing of the design indicated that this single mirror design produces good image quality. The optics have been procured and mounts fabricated. A circular variable filter wheel with segments covering 2-14 microns has been procured and will give 3% bandwidth at 10 microns when located at the pupil stop. With care in preventing light leaks, the CVF will permit moderate background imaging outside the dewar without additional optical attenuation. Very low background imaging in the lab will be achieved with neutral density filters. Electrical instrumentation of the dewar is proceeding. A new Si:Ga 58 x 62 pixel DRO detector was procured with SRT funds and will be delivered in October 1986. The imaging dewar will be operational in early FY 87.

New 2 microsecond 16 bit A/D converters have been received and installed in new A/D sampling boards designed specifically for the DRO detectors, as part of a new front-end "bit slice" processor for optimization of DRO imaging array operation. A digital sampling scheme has been developed which will permit a rigorous correlated double sampling approach, with very flexible, powerful array processing hardware for high speed calculations. The new system will be detector speed limited. The electronic fabrication of the bit-slice processor and coefficient memory has been completed and successfully tested. The analog front-end electronics, including low-noise preamps, precision bias supplies and

timing generator interface have been designed, fabricated, and are being tested. A separate back-up detector test set has been assembled to permit detector testing to be carried out independent of the front-end processor development, to permit operation of the array camera, and to minimize the danger of single point system failure.

1.6.4 Optical Design Program (Code 717.4) -

1.6.4.1 IRAC Optical Specification Status -

During most of the IRAC design study pixel sizes of 50μ for band 1 and 100μ for bands 2 and 3 were assumed. The current optical specification is for the wide field 80% encircled energy spot diameter to be less than the pixel size or diffraction-limited and for the narrow field to be less than the pixel size and diffraction-limited. In the latter part of this design study performances of designs with pixel sizes up to 75 microns were considered for input into an ongoing pixel size tradeoff study being performed by SBRC.

1.6.4.2 Refractive Optical Designing -

Refractive singlet designs for all three bands were first studied. Cesium iodide emerged as the optimum material for all three designs. The band 1 design did not meet the 50μ pixel specification at 300°K. Bands 2 and 3 singlet designs met the 100μ pixel specification at 300°K. Since IRAC must operate at a 4°K temperature, refractive index tolerancing was performed on these designs. For bands 2 and 3 to meet the wide field requirements over their respective spectral ranges at 4°K, a cryogenic refractive index measurement uncertainty of about ± 0.001 would be

required. Both the measurement of the refractive index and the thermal expansion coefficient of cesium iodide at 4°K has not been documented in literature. In terms of a back focal length measurement tolerance, band 2 was $\pm 236\mu$ and band 3 was $\pm 170\mu$.

A silicon/germanium air-spaced achromatic doublet was designed for band 1. This design was an improvement on the cesium iodide singlet which did not meet specification due to chromatic aberration and field curvature. A worst case wide field 80% encircled energy spot diameter of 35.2μ was achieved at 300°K. The back focal length measurement tolerance was $\pm 86\mu$ which appeared to be within the capability of a breadboard metrology setup. AR coating technology does exist for maximizing the transmittance of germanium and silicon.

1.6.4.3 Reflective Optical Designing -

Reflective IRAC designs were looked at initially out of concern for chromatic aberration and cryogenic uncertainties of refractive indices and thermal expansion coefficients at 4°K. A number of two mirror concepts were studied in conjunction with the use of a spherical titled collimator. All of these designs suffered from first order limitations, mostly due to image inaccessibility or obscurations. Tilting and decentering the mirrors to avoid these limitations resulted in poor image quality.

The collimator was then allowed to be an aspheric mirror (first a parabola). A baseline off-axis unobscured two parabolic mirror design resulted where the first parabola was the collimator. Further optimization of this design resulted as a hyperbolic collimator (primary) and an elliptical imager (secondary). The clearance of the top of the detector to

avoid obscuration is what determined the amount of secondary mirror tilt and limited image quality. The insertion of a flat tilt mirror at the pupil stop following the collimator and making the design slightly non-telecentric resulted in successfully moving the detector behind and below the tilt mirror where there is no physical constraint on the detector package size. The beam clearance from the flat tilt mirror now determines the amount of secondary mirror tilt to avoid obscuration. For the 65μ pixel size case, a secondary tilt of 10.9 degrees resulted in a worst case 80% encircled energy spot diameter of 53.1μ . This optical configuration is currently feasible for pixel sizes of 65μ or greater even without varying from parabolas on both the primary and secondary mirrors. Further optimization is possible by modifying the flat tilt mirror to a reflecting Schmidt corrector.

1.6.4.4 Recommendations -

A strong recommendation must be given to the three mirror design which successfully eliminated detector packaging constraints while improving the image quality. With further optimization, this three mirror design should be capable of handling a pixel size down to 60μ for band 1. The band 1 achromatic doublet does outperform this reflective design at 300°K but it is much more difficult to align and requires much more manpower and funds to achieve the required performance at 4°K. The three mirror design is superior for bands 2 and 3 and is currently well within the specification. For the next few months, optimization on this three mirror design will be performed along with considering a few alternate three mirror design concepts. Catadioptric designs will also be considered once again.

1.7 Ames Research Center - Band III Effort (Si:Sb Arrays)

Our IRAC technology development activities focussed on the development and evaluation of the SBRC 58 x 62 Si:Sb arrays, the baseline device for IRAC Band III.

1.7.1 Development Contract NAS2-12110 (Santa Barbara Research Center) -

During the March - June period, additional low-temperature (<7 kelvin) testing of the Si:Sb arrays was carried out at SBRC under a contract extension. It was found that at the lowest temperature used (3.2 kelvin chip temperature) the signal and noise levels of the array were close to those measured at higher temperatures. The signal at 3.2 K was about 10 - 20% lower than at 7K, but the noise remained unchanged, within experimental uncertainty. This may be an important result for SIRTF applications of DRO multiplexers, since it establishes that no particular sensitivity penalty is incurred in operating at very low temperatures (e.g. for suppression of dark current).

An engineering model (S/N 2) of the Si:Sb arrays was delivered to Ames in June, and on June 20 we received copies of the contract Final Report (SBRC Report 61471). The report was not complete, so a letter requesting supplementary information was prepared and sent to SBRC. The SBRC addendum provides the missing information (such as device capacitance and the values of DC and clocked voltages used in the testing); the report and addendum will be distributed to the SIRTF community as a NASA Contractor Report in the near future. On June 30 the two contact deliverable arrays (S/N 1 and S/N 3) were hand-carried back to Ames.

In late June we detected our first IR signal from the engineering Si:Sb array. Although the RA05, CA 05, and CA 06 row and address enable clocks were known to be inoperative, proper operations was obtained on small subsets of the array. Subsequent ARC tests with S/N 3 indicated an intermittent problem with the RA 05 clock. SBRC had noticed this problem, but attributed it to a dewar wiring problem. After consultation with SBRC, it was agreed that this (largely unworkable) array would be returned, and their next best Si:Sb device, the Hughes-Carlsbad-produced S/N CB, would be supplied in its place. We received the CB array in mid-September. Very recent and limited tests at Ames of S/N 1, which is presumably the best SBRC array, uncovered a banded output, where the output of pixels addressed through the RA 02 clock displayed a slower time response and a different output signal level than the remaining ~60% of the array. Tests with a curve tracer indicated a "soft gate" on RA 02; this problem was not noticed by SBRC before delivery, and it will be investigated in detail.

1.7.2 ARC Testing Program -

A significant amount of effort was devoted to completing and debugging the low-background dewar system, the drive/readout electronics, and the system software for this project.

The 68-pin leadless carrier to which a loaned SBRC InSb DRO array was mounted cracked during a cooldown in our dewar in May. Following this, we designed and installed a new mechanical mount for the arrays which decoupled the spring forces used to thermally interface and electrically contact the carrier. Subsequent tests with blank carriers and hybrid arrays have indicated no further problems. The dewar is now (relatively) mechanically and electrically reliable, and we are now able to routinely

and efficiently cool down and operate test arrays.

The noise level and sources of noise in the drive/readout electronics have been investigated. The analog correlated-double-sample board was identified to be a prime contributor of extra pickup; with support from the project programmers, this function has been re-implemented digitally, with a significant reduction in noise. While various noise spikes are still present in the system, one can time the sample locations in the output waveform selectively, and avoid substantial pickup. The dewar-mounted preamplifiers were also modified to allow their bandpasses to be digitally selectable.

The data acquisition software developed for our 16 x 16 Si:Bi AMCID array, resident on a Masscomp machine, was modified and successfully installed on the Sun 2/120 computer used as the host for this project. Software to drive the Ethernet connection between the drive electronics boards (located in a VME chassis) and the Sun was developed and made operational. The array control and data acquisition program was successfully modified to include (a) digital correlated double (or triple) sampling, (b) calculation of standard deviations (i.e. noise statistics), (c) fast Fourier transforms of array data, and (d) nondestructive readout of the array. We can now digitize and display (grey-scale and histogram images of) data from the full 58 x 62 field or arbitrary subsets of the field. Finally, the ultimate version of computer-control for this phase of the project was planned, and coding was begun. A Macintosh Plus was acquired for this purpose, and the windowing and menu capabilities of the machine will be utilized to specify and direct the Sun's overall operation.

Testing at the moment is aimed at reducing system noise and verifying that noise levels computed through the computer-based system correspond to levels measured independently with stand-alone FFT spectrum analyzers. Our work in the near term will concentrate on optimization of the array operating parameters (bias and clock voltages, the timing of sample pulses, reset duration, etc.), and initial noise and signal characterizations.

1.8 University of Arizona -- Optical Design

The University of Arizona continued its routine oversight of GSFC optical design technical memos as they were released, by telephone contact with GSFC Code 717, and by telecon participation. Arizona received the OCLI beam splitters procured by SAO in September 1986 and has completed the facility to perform an independent evaluation of their performance. Beam splitter testing is expected to begin in October 1986.

2.0 WORK PLANNED FOR NEXT REPORTING PERIOD

Activity under this grant will phase down during the next reporting period and phase up under the new Definition Phase contract which is expected to start in November 1986. Activity expected to continue under the grant includes completion of InSb array testing and delivery of the InSb and Si:In arrays in late November 1986 with a Final Report on the array effort expected in December 1986. This will be followed by DRO optimization studies and tests which are expected to be complete by the end of March 1987.

The next IRAC Science Steering Committee meeting will be held October 23 and 24, 1986 at SAO and will include a review of detector development and optical design status, review and approval of the Instrument Requirements Document, review of FY87 Definition Phase effort, discussion of alternate focal plane proposals, development of a coordinated detector tradeoff study plan, and preparation for the December 1986 SWG meeting. The detector tradeoff study plan will focus on identifying and implementing those analytical studies and tests essential to selection of optimized detectors for the instrument. The plan will include consideration of all areas of the program likely to impact detector performance including optical and thermal design, mission operations, data analysis, and so forth.

Detector test effort at Rochester, Ames and GSFC and optical research, including beam splitter tests at Arizona, will continue for about two months under the grant - that is, until the Definition Phase contract is in place.

FY87 Definition Phase activity is detailed in the IRAC Study Plan, Volume II of P1376-11-83, Revision 4 and IRAC-104.

APPENDIX A

GSFC STATUS REPORT OF SEPTEMBER 1986

SMITHSONIAN INSTITUTION
ASTROPHYSICAL OBSERVATORY
60 GARDEN STREET CAMBRIDGE, MASSACHUSETTS 02138
TELEPHONE 617 495-7000

M E M O R A N D U M

To: IRAC Team

From: Richard S. Taylor, *Dile* IRAC Program Manager

Subject: GSFC Status Review - September 9, 1986

Date: September 11, 1986

Attached are copies of the handouts from this month's GSFC technical and program status review meetings. The morning technical meeting focussed on optical design results and planning FY87 work at GSFC. There was no discussion of detector results since Gerry Lamb was not present.

The results of the latest optical study show that the clearance between the nearest edge of the Band I array to the optical path can be increased to 9mm but that the analysis must be rerun to accurately account for the physically larger 75 micron pixel array. We also discussed the possibility of locating the detectors behind and below the Schmidt corrector plate. This looks feasible and the concept will be considered for future analysis.

Action Items

1. Taylor prepare agenda and set date for next SSC meeting, probably about mid-October at SAO. This meeting will be to review program technical status and plan FY87 work in detail.
2. Maymon re-do optical ray path clearance analysis for 134 x 134 array (allows 6 dead rows and columns in blind cross) and 75 micron pixels.
3. Cooley develop GSFC task list by early October for review by SAO and SSC.
4. Cooley provide comments on suggested IRD format to SAO.
5. Taylor redraft IRD based on Cooley inputs and Gezari draft by mid-October. Outline by 9/21/86.

Attachment

RST/mlh

AGENDA
SIRTF/IRAC TECHNICAL MEETING
SEPTEMBER 9, 1986

- o DISCUSS OVERALL SIRTF/IRAC PROGRAM STATUS
 - PROPOSAL
 - SCHEDULE
 - FUNDING
- o DISCUSS INPUTS FOR SEMI ANNUAL REPORT & TECHNICAL STATUS REPORT
 - DETECTOR TESTS
 - 724 -
 - 697 -
 - OPTICAL STUDIES
 - 717 -
 - OTHER
- o DISCUSS TECHNOLOGY DEVELOPMENT TASKS FOR FY '87
 - DETECTOR TESTS
 - 724 - DARK CURRENT, READ NOISE, IMAGING
 - 697 -
 - OTHER -
 - OPTICAL STUDIES
 - 717 - REFRACTIVE, REFLECTIVE, ETC,
 - OTHER -
 - OTHER
- o DISCUSS NEXT CO-I MEETING
 - DATE -
 - TIME
 - SUBJECT
- o DISCUSS NEXT SSC MEETING
 - DATE
 - TIME
 - SUBJECT

*Out. Requirements
Document*

AGENDA

- o SBRC MEETING - SEPT, 19TH
- o DETECTOR SIZE
- o P. MAYMON COMMENTS - OPTICAL STUDIES
- o G. LAMB COMMENTS - DETECTOR TESTS

September 9, 1986

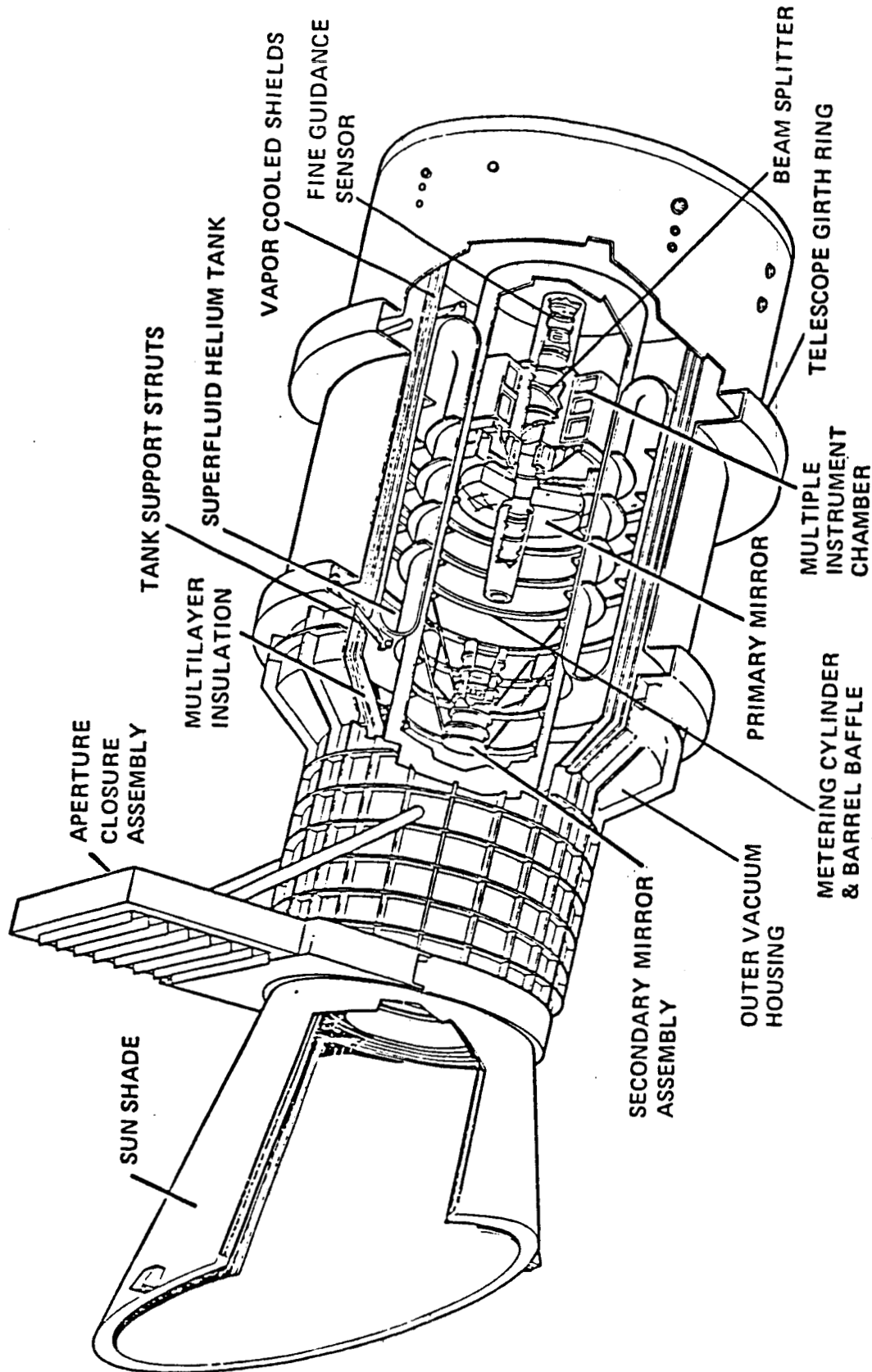
SIRTF
INFRARED ARRAY CAMERA (IRAC)

PRINCIPAL INVESTIGATOR: GIOVANNI FAZIO (SAO)
PROGRAM MANAGER: DICK TAYLOR (SAO)
SCIENCE STEERING COMMITTEE: GIOVANNI FAZIO (SAO)
DAN GEZARI (GSFC)
WILLIAM HOFFMAN (UA)
GERALD LAMB (GSFC)
CRAIG MCCREIGHT (AMES)
JUDITH PIPHER (UR)
DAN GEZARI (GSFC, 697)
JIMMY COOLEY (GSFC, 697)
GORDON CHIN (697)
DAN GEZARI (697)
GERALD LAMB (724)
JOHN MATHER (697)
ROBERT SILVERBERG (697)
PETER SHU (725)

INSTRUMENT SCIENTIST:
INSTRUMENT MANAGER:
GSFC CO-INVESTIGATORS:

OBJECTIVE: TO OBTAIN HIGH SENSITIVITY, HIGH SPATIAL RESOLUTION PHOTOMETRY OF INFRARED ASTRONOMICAL SOURCES, USING ARRAY FOCAL PLANE DETECTORS IN A LONG LIFE-TIME MISSION WITH THE SIRTF TELESCOPE, IN A BROAD PROGRAM OF OBSERVATIONAL ASTROPHYSICS.

SIRTF TELESCOPE CONFIGURATION



SIRTF REFERENCE CONCEPT
FALL 1985

HIGHLIGHTS

1. SIRTf/IRAC SR&T (CODE 697) - LABORATORY NOW OPERATIONAL. EQUIPMENT REPAIR AND LAB MOVE ACCOMPLISHED. REVISED WORK SCHEDULE WILL NOT AFFECT OVERALL SIRTf/IRAC SCHEDULE.
2. SIRTf/IRAC OPTICAL STUDY (CODE 717) - SCHEDULED TASKS (REFRACTIVE AND REFLECTIVE) COMPLETED FOR FY '86. FIFTH INTERIM REPORT COMPLETED.
3. SIRTf/IRAC ARRAY DETECTOR TESTS (CODE 724.3) - COMPLETED READ NOISE AND DARK CURRENT TESTS. INTERIM REPORT COMPLETED. IMAGING TESTS TO START IN SEPTEMBER.
4. No BUDGET OR MANPOWER PROBLEMS.

GODDARD SPACE FLIGHT CENTER		NARRATIVE ANALYSIS		ORIGINAL SCHEDULE APPROVAL <u>May '86</u> (DATE)	
APPROVAL RESPONSIBILITY <u>SAO/GSFC Code 600</u>		PROJECT: <u>SIRTF INFRARED ARRAY CAMERA (IRAC)</u>		LAST SCHEDULE CHANGE <u>Sept. 9, 1986</u> (DATE) (NO.) (INITIALS)	
ACCOMPLISHMENT RESPONSIBILITY		SCHEDULE NO.: <u>2</u> of <u>4</u>		STATUS AS OF <u>Sept. 9, 1986</u> (DATE) (INITIALS)	

The 697 array camera lab move was completed on August 15. The new location is Bldg. 2, Room 222, and the new lab is operational.

The Optical Imaging Test Dewar assembly is now scheduled for completion by the end of October and initial testing completed by December 1.

The DR0 Array delivery from SBRC is set for mid September. The A/D and detector bias printed circuit P.C. boards for the Bit Slice Processor has been delivered. All electronic components have been received and assembly of the boards is underway and expected to be completed by October. The Timing generator interface board P.C. layout has been completed. The prototype Bit Slice Processor breadboard will undergo final checkout in September.

The SAR contract task for the SR&T Detector in Code 697 has been redirected to make more efficient use of the funds and manpower available for this task.

The strawman Interface Requirements Document has been delivered but no response has been received from SAO or the IRAC Team. In view of the overall SIRTF/IRAC program schedule delay this is a low priority.

Code 717 (Optical Studies Section)

The Optical Design Section (717.4), working with Bill Hoffman (University of Arizona), is performing design studies on the IRAC Optics. Specific areas of study include refractive, reflective, and catadioptric configurations. Computer aided techniques are used to model and evaluate the system design.

Code 717 reports that the optimization of the refractive design has been completed, thus concluding the refractive tasks in FY '86.

NOTES:

GODDARD SPACE FLIGHT CENTER		NARRATIVE ANALYSIS		ORIGINAL SCHEDULE APPROVAL May '86 (DATE)	
APPROVAL RESPONSIBILITY SAO/GSFC Code 600		PROJECT: SIRTf INFRARED ARRAY CAMERA (IRAC)		LAST SCHEDULE CHANGE (DATE) (NO.) (INITIALS)	
ACCOMPLISHMENT RESPONSIBILITY		SCHEDULE NO.: Page 3 of 4		STATUS AS OF Sept. 9, 1986 (DATE) (INITIALS)	

The catadioptric design study, under the reflective tasks, has been completed early due to the success of the reflective Schmidt concept. No viable catadioptric design has emerged from this study.

The three-mirror off-axis design study has been completed for FY'86. Some final optimization of this design will be continued under the "optimization of final design" scheduled task #17. A reflecting Schmidt corrector was added to the previously discussed two-mirror off-axis design. This achieved more clearance for the detector (while not obscuring any rays) and improved spot sizes. Typical improvements are given in P. Maymon's attached report, page 15.

The fifth IRAC optical design interim report was released on Aug. 21st.

Code 717 recommends that the three-mirror off-axis design study be continued in FY '87.

Code 724 (Instrument Microelectronics and Detector Branch)

The evaluation and testing of the Band II DRO Array Detector is continuing in the Code 724.3 laboratory. The three principal areas of study are read noise level, dark current, and image resolution.

The Interim Report on the operation and performance (read noise and dark current) of the DRO device has been completed. The crude imaging test will begin in September.

NOTES:

GODDARD SPACE FLIGHT CENTER		NARRATIVE ANALYSIS		ORIGINAL SCHEDULE APPROVAL May '86 (DATE)	
APPROVAL RESPONSIBILITY SAO/GSFC Code 600		PROJECT: SIRTf INFRARED ARRAY CAMERA (IRAC)		LAST SCHEDULE CHANGE (DATE) (NO) (INITIALS)	
ACCOMPLISHMENT RESPONSIBILITY		SCHEDULE NO.: Page 4 of 4		STATUS AS OF Sept. 9, 1986 (DATE) (INITIALS)	

Code 725 (Instrument Systems Branch)

Continues to support Code 724 in laboratory detector tests. Peter Shu (SIRTf Systems Engineer) has been detailed to the COBE project for a period of time.

Budget and Manpower

An additional 506 authority (total of 119K) has been received from ARC. This allocation fully funds SIRTf/IRAC to 119K for FY '86.

Other

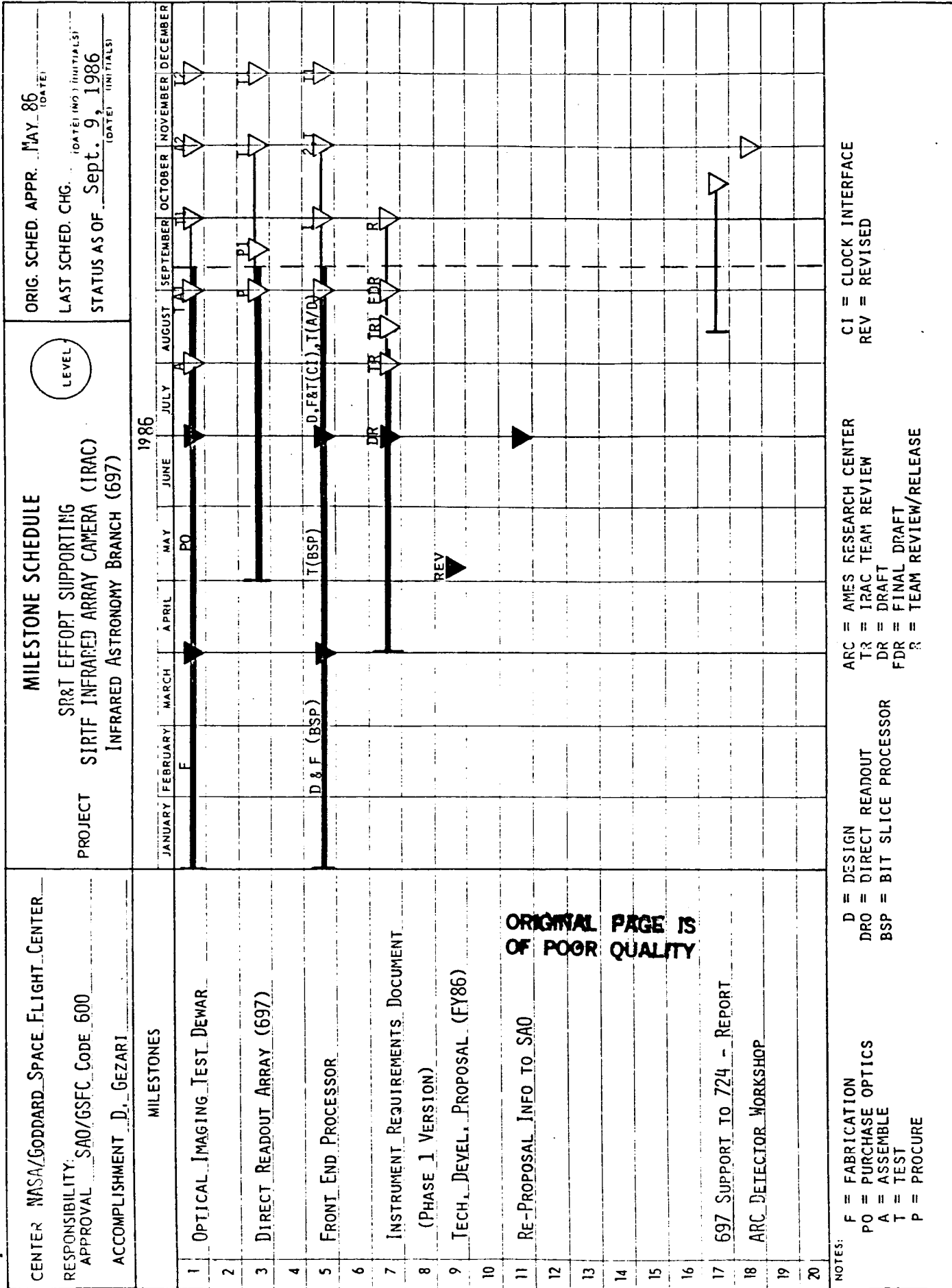
A technical review meeting was held on September 9, 1986. Pete Maymon (optical studies) and Gerry Lamb (detector tests) presented the latest results on the Instrument Development tasks.

The GSFC SIRTf/IRAC Definition Phase proposal (Study Plan and Cost Plan) has been circulated to Code 650, 286, 700, 697, etc. for final comments.

A Co-I meeting was scheduled for Aug. 18, but was cancelled due to vacation, leave, etc. Additional meetings are planned; including a session to discuss, plan, and schedule GSFC Instrument Development work (detector development, optical studies, etc.) for FY '87.

The Space Infrared Telescope Facility Infrared Array Camera (SIRTf/IRAC) Letter of Agreement has been received from SAO. A response has been prepared stating the LOA is acceptable, but emphasizing that the GSFC conditions and exceptions, included in the SAO proposal to ARC, shall be a part of the final negotiated contract and SOW.

NOTES:



1 YEAR

CENTER NASA/GODDARD SPACE FLIGHT CENTER
 RESPONSIBILITY: SAO/GSFC Code 600
 APPROVAL
 ACCOMPLISHMENT PETER MAYMON

MILESTONE SCHEDULE

PROJECT SIRTIF INFRARED ARRAY CAMERA (IRAC)
 OPTICAL DESIGN (717.4)

ORIG. SCHED. APPR. MAY 86
 (DATE)

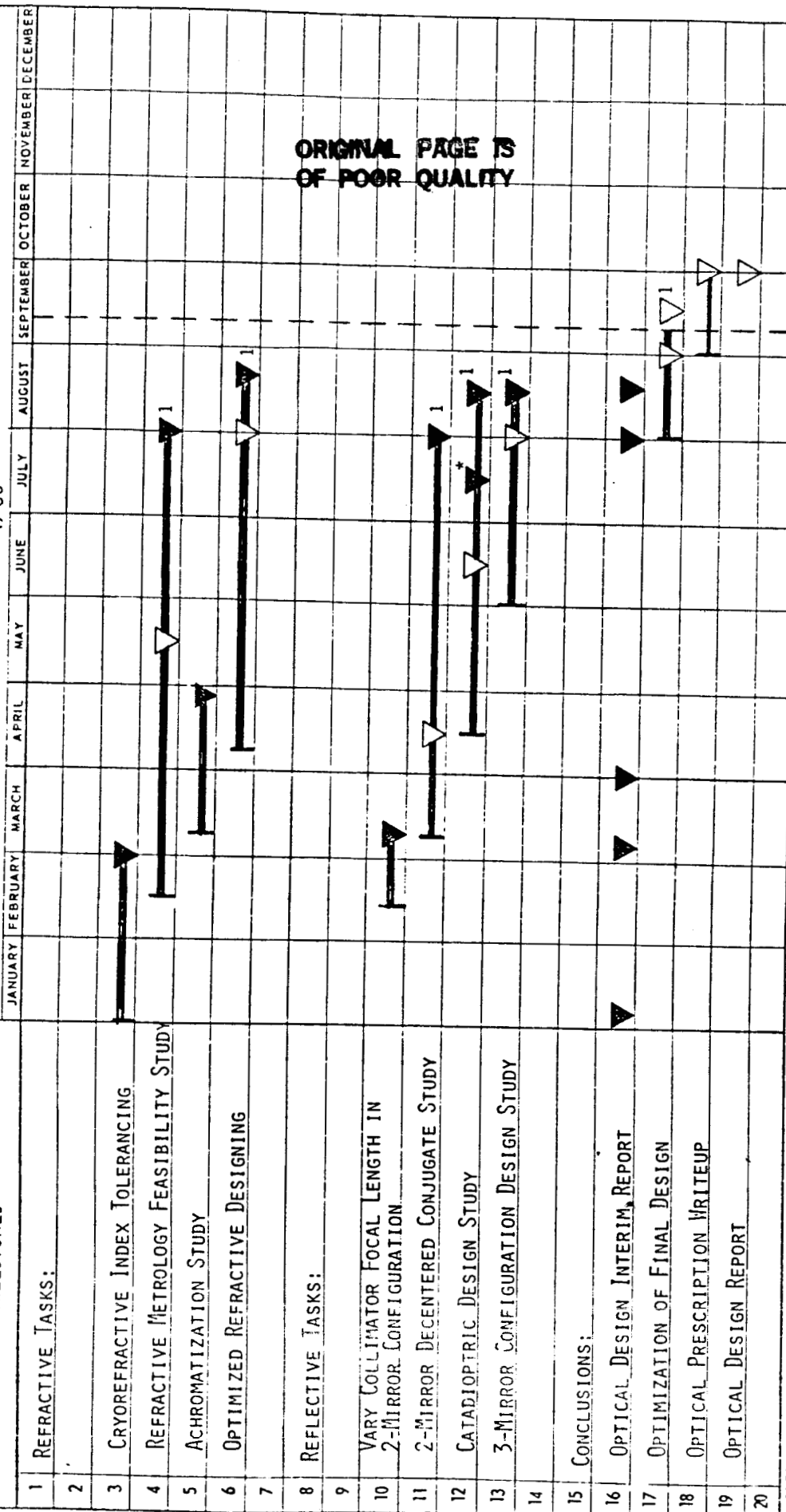
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STATUS AS OF Sept. 9, 1986
 (DATE) (INITIALS)

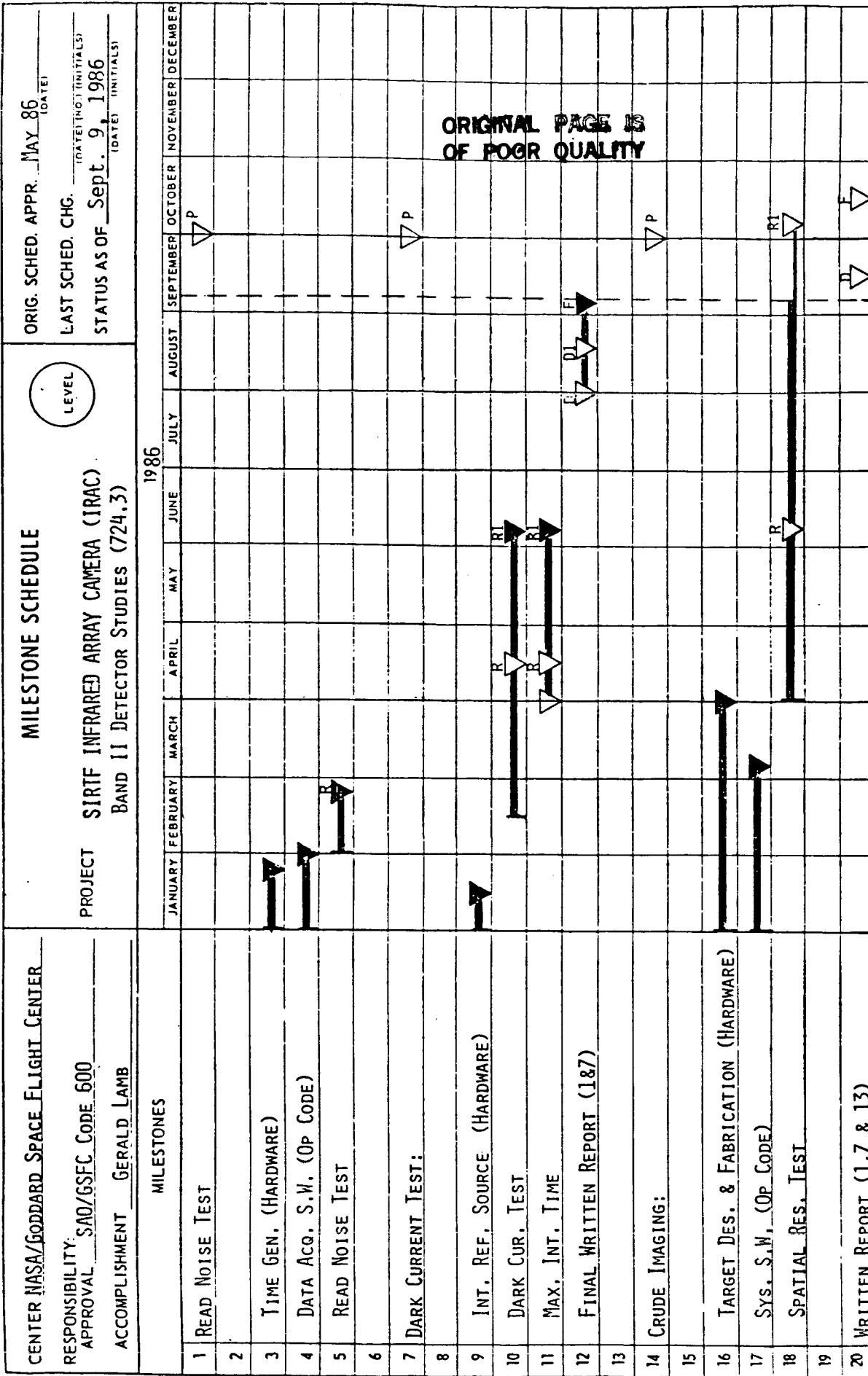
LEVEL

MILESTONES

19 86



NOTES: 1,2,3 ... = SCHEDULE DELAYS
 * Completed Early



ORIGINAL PAGE IS
OF POOR QUALITY

NOTES:

R = ORAL REPORT

D = DRAFT REPORT

F = FINAL REPORT

1,2,3 = SCHEDULE DELAYS

P = PROPOSE TO CONTINUE IN FY87.

September 2, 1986

To: Jimmy Cooley (IRAC Instrument Manager)/697
From: Optical Design Section/717.4
Subject: INFRARED ARRAY CAMERA (IRAC) HIGHLIGHTS

The fifth IRAC optical design interim report was released on August 21st.

REMAINING FY86 OPTICAL DESIGN TASKS

(1) OPTIMIZATION OF REFRACTIVE DESIGNS

The addition of a field flattener lens to the singlet designs for all three bands was tried. There was a decrease in field curvature but with a comparable increase in chromatic aberration. No appreciable decreases in spot sizes were achieved with the field flattener. Achromatic doublet designing for bands 2 and 3 was cancelled due to the successful performance of the cesium iodide singlet and the concentration on reflective designs. This task is completed for FY86.

(2) THREE-MIRROR OFF-AXIS DESIGN STUDY

To achieve more clearance for the detector such that it will not obscure any rays, a reflecting Schmidt corrector has been added to the previously discussed two-mirror off-axis design. More clearance and improved spot sizes were achieved. For example, a 9.3mm detector clearance design achieved a worst case 80% radial energy spot diameter (80%RESD) of 67.0μ located at the two bottom corners of the detector. A 5.2mm detector clearance design achieved a worst case 80%RESD of 56.9μ at the two bottom corners of the detector. Without the reflecting Schmidt corrector, only detector clearances up to approximately 5mm were allowed presuming a maximum pixel size of 75μ for all three bands. This task is now completed for FY86 with final optimization of the above design included in the optimization of the final design task. It is recommended that this task be picked up again in FY87 since there are a few other configurations that might be viable candidates.

(3) CATADIOPTIC DESIGN STUDY

This task was completed prematurely due to the success of the reflective Schmidt concept. So far no viable catadioptric design had been found. If necessary this task could be continued next year (FY87).



Peter W. Maymon

September 4, 1986

To: Jimmy Cooley (IRAC Instrument Manager)/697

From: Microelectronic Section/724.3

Subject: Monthly SIRT/IRAC Detector test Report

The generation of the Interim Report on the DRO read noise and dark current has been the primary effort this month. All data taken for this report has been reduced and a detailed paper on the operation and performance of the DRO device will be available for the September review meeting. This report is submitted in place of a technical review for this month.

Crude Imaging

The necessary hardware and software are in place for the crude imaging tests. This includes the image acquisition software and image data reduction software. All hardware modifications are in place with the exception of two problems. During the Installation of the new hard disk drive the data acquisition preprocessors developed a 'bug' where data acquisition is not possible through the system. This problem is under investigation and is not expected to create a delay. Also, the internal reference source developed a short in the diode temperature sensor. Since there are close tolerances within the ultraminature housing this is not a surprise. This is also not expected to create a delay in the crude imaging tests planned for this month.

Summary

The Interim Report on the Si:Ga DRO performance will be submitted at the monthly meeting. The crude imaging tests are planned for this upcoming month will be conducted.

Gerald M. Lamb/724.3

SIRTF INFRARED ARRAY CAMERA

(IRAC)

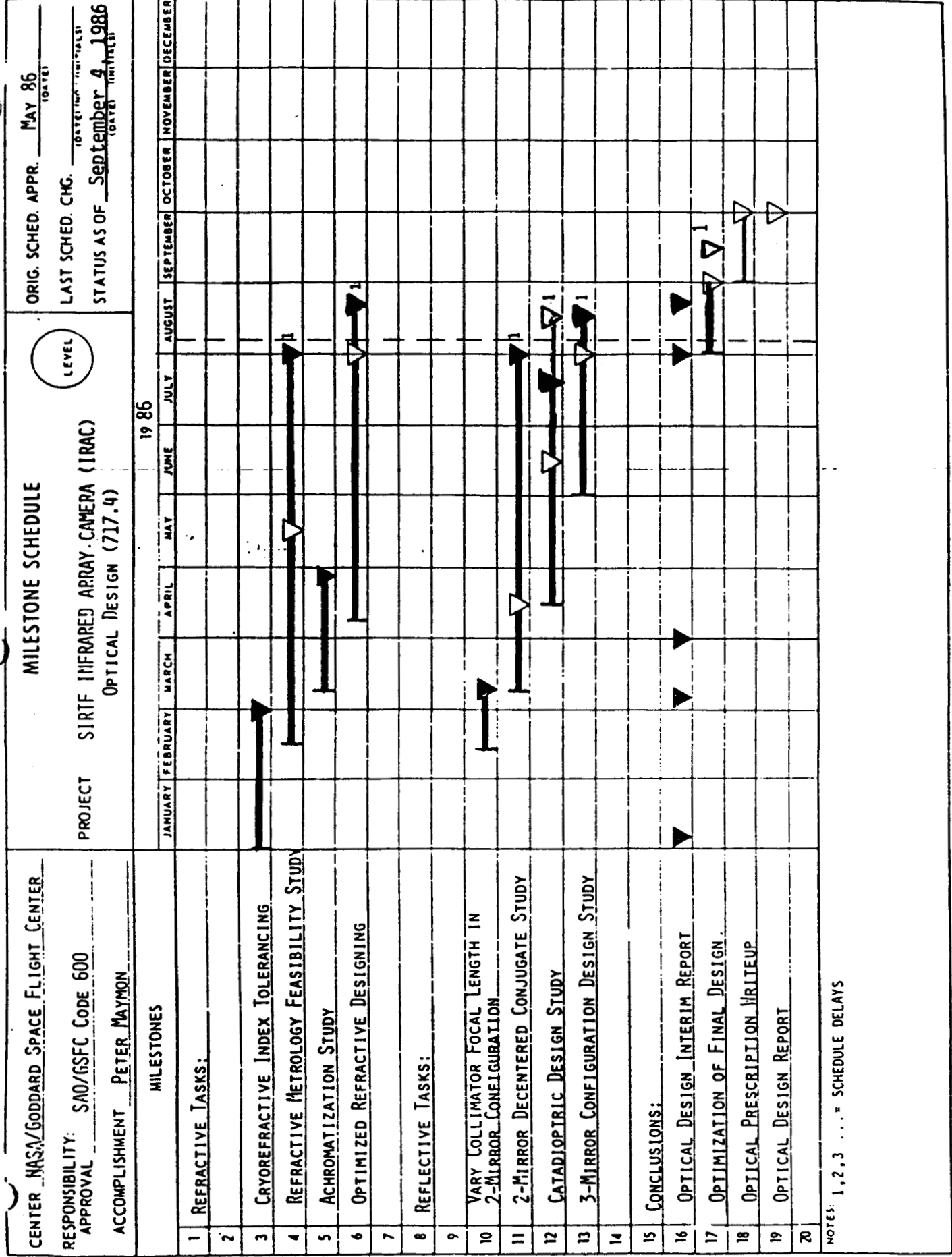
OPTICAL DESIGN STUDY
TECHNICAL REVIEW

PETER MAYMON

CODE 717.4

SEPTEMBER 9, 1986

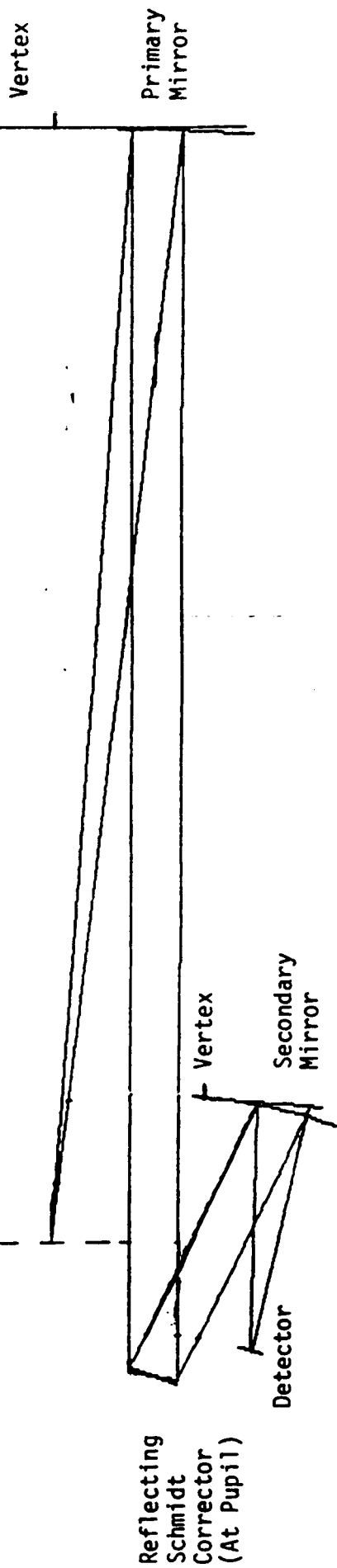
1 YEAR



NOTES: 1,2,3 ... = SCHEDULE DELAYS

IRAC -- TWO OFF-AXIS UNOBSCURED ASPHERIC MIRRORS
PLUS A REFLECTING SCHMIDT CORRECTOR

SIRTF Focal Plane



IRAC -- 2 ASPHERES + SCHMIDT REFL COR 19MM CLER
30.000000 LENS Y-Z PROFILE

INFRARED ARRAY CAMERA (IRAC) OPTICAL DESIGN EVALUATION

CONFIGURATION: TWO OFF-AXIS UNOBSURED ASPHERIC MIRRORS
PLUS A REFLECTING SCHMIDT CORRECTOR

WIDE FIELD CASE (FOV = 300 SEC)

IMAGE QUALITY DEGRADATION WITH INCREASING CLEARANCE BETWEEN
THE EDGE OF THE DETECTOR'S ACTIVE AREA AND THE BOTTOM EDGE
OF FIELD RAY REFLECTED FROM THE REFLECTING SCHMIDT CORRECTOR.

80 PERCENT ENCIRCLED ENERGY DIAMETER (MICRONS)
@ Y FIELD ANGLE (ARC SEC)

CLEARANCE	SECOND. X FIELD TILT ANGLE	-150sec	0sec	150sec
5.18mm	13.9°	0sec	22.0μ	22.6μ
		75sec	27.5μ	25.7μ
		150sec	41.6μ	37.0μ
7.11mm	15.7°	0sec	28.5μ	25.5μ
		75sec	34.0μ	29.5μ
		150sec	51.7μ	40.9μ
8.31mm	16.5°	0sec	35.7μ	48.1μ
		75sec	38.9μ	48.7μ
		150sec	34.6μ	48.9μ
9.26mm	17.4°	0sec	46.1μ	57.9μ
		75sec	47.1μ	57.7μ
		150sec	44.4μ	61.4μ
10.26mm	18.3°	0sec	50.7μ	62.9μ
		75sec	50.5μ	63.6μ
		150sec	49.4μ	62.8μ

BACK FOCUS ERROR (MICRONS) THAT PRODUCES WORST CASE
80%RESD EQUAL TO SPECIFIC PIXEL SIZE (MICRONS)
AND/OR DIFFRACTION-LIMITED SPOT DIAMETER

50μ pixels
6.4mm x 6.4mm

CLEARANCE	PIXEL SIZES (MICRONS)					
	50μ	60μ	65μ	70μ	75μ	100μ
5.18mm	0	-83/+128	-131/+179	-174/+223	-213/+264	-393/+439
7.11mm	0	0	-91/+84	-162/+138	-205/+182	-388/+371
8.31mm	0	0	-83/+66	-223/+137	-290/+86	-539/+356
9.26mm	0	0	0	-134/+74	-294/+105	-549/+274
10.26mm	0	0	0	0	-62/+47	-497/+271

footnote

NOTE: -- ENCIRCLED ENERGY VALUES ARE FOR A FLAT AND TILTED FOCAL SURFACE.

50μ pixels
will go down to ~6μm max
with 75μ pixels

100 micron
clearance
minimum

INFRARED ARRAY CAMERA (IRAC) OPTICAL DESIGN EVALUATION

CONFIGURATION: TWO OFF-AXIS UNOBSURED ASPHERIC MIRRORS

WIDE FIELD CASE (FOV = 300 SEC)

IMAGE QUALITY DEGRADATION WITH INCREASING CLEARANCE BETWEEN
THE EDGE OF THE DETECTOR'S ACTIVE AREA AND THE BOTTOM EDGE
OF FIELD RAY REFLECTED FROM THE FIRST MIRROR.

80 PERCENT ENCIRCLED ENERGY DIAMETER (MICRONS) @ Y FIELD ANGLE (ARC SEC)					
CLEARANCE	SECOND. TILT	X FIELD ANGLE	-150sec	0sec	150sec
1.83mm	10.6°	0sec	53.6μ	45.2μ	55.7μ
		75sec	54.7μ	45.8μ	55.6μ
		150sec	57.5μ	50.2μ	57.5μ
2.84mm	11.4°	0sec	57.8μ	49.4μ	60.9μ
		75sec	60.2μ	50.3μ	60.3μ
		150sec	63.2μ	56.7μ	63.4μ
3.84mm	12.3°	0sec	59.7μ	53.9μ	65.8μ
		75sec	63.7μ	64.9μ	65.3μ
		150sec	68.7μ	60.6μ	68.7μ
4.69mm	13.1°	0sec	68.0μ	59.0μ	69.6μ
		75sec	68.5μ	59.8μ	69.5μ
		150sec	70.9μ	63.6μ	70.9μ
5.64mm	13.9°	0sec	62.5μ	63.8μ	74.8μ
		75sec	64.2μ	63.9μ	74.5μ
		150sec	66.8μ	64.6μ	74.9μ

NOTE: -- ENCIRCLED ENERGY VALUES ARE FOR A FLAT AND TILTED FOCAL SURFACE.

CONCLUSION

- 2 ASPHERE PLUS SCHMIDT CORRECTOR
ACHIEVES MORE DETECTOR CLEARANCE
WITH IMPROVED IMAGE QUALITY
- THE MINIMUM CLEARANCE FOR THE DETECTOR
NEEDS TO BE DETERMINED TO DETERMINE
THE MINIMUM PIXEL SIZE ALLOWED

APPENDIX B

IRAC DOCUMENT AND MEMO LIST

Wide Field and Diffraction Limited
Array Camera (IRAC) for SIRTF

TECHNICAL DOCUMENTS
and
TECHNICAL MEMORANDA

22 October 1986

NASA Goddard Space Flight Center

NASA Ames Research Center

University of Arizona
Steward Observatory

University of Rochester
Department of Physics and Astronomy

Smithsonian Institution
Astrophysical Observatory
60 Garden Street
Cambridge, Massachusetts 02138

5.0 IRAC 500-599 Thermal and Mechanical System Reports

6.0 IRAC 600-699 Electronics System Technical Reports

7.0 IRAC 700-799 Ground Support Equipment Technical Reports

8.0 IRAC 800-899 Data Reduction and Analysis Reports

9.0 IRAC 900-999 Mission Operations Reports

10.0 IRAC/TM 1000-1999 Program Management And Planning Technical Memos

TM-1001 "Definition Phase Program Plan - Technical Issues"
R. Taylor 27 March 1985

11.0 IRAC/TM 2000-2999 Science And Telescope Requirements Technical Memos

TM-2001 "SIRTF Pointing and Stabilization Study"
G. Fazio 7 November 1979

TM-2002 "Science Priorities - Summary of Views of IRAC Team
Members"
D. Gezari November 1984

TM-2003 "SIRTF Requirements Review Action Items for 11/15/84"
G. Fazio 13 November 1984

TM-2004a "Temperature Limits for the SIRTF Sunshield, Forebaffle
and Aperture Cover"
A. Dinger 19 March 1985

TM-2004b "Lunar Avoidance for SIRTF"
A. Dinger 19 March 1985

TM-2005 "Division of Responsibilities for Photometric
Observations with SIRTF Focal-Plane Instruments"
G. Fazio, G. Rieke 11 April 1985

TM-2006 "Image Quality of the Ritchey-Chretien and Coma-
Compensated Optical Designs"
7 May 1985

TM-2007 "SIRTF Stray Radiation as a Function of Solar Angle"
A. Dinger 8 May 1985

TM-2008a "Background Limits to Performance of SIRTF, Rev. A"
G. Rieke 22 July 1985

TM-2008b "Background Limits to Performance of SIRTF, Rev. B"
G. Rieke 15 August 1985

TM-2008c "Comments on Rieke Memo 'Background Limits to Performance
of SIRTF'"
S. Willner, J. Pipher 7 November 1985

TM-2009 "Mapping Requirements for SIRTF"
J. Pipher 8 August 1986

12.0 IRAC/TM 3000-3999 Detector System Technical Memos

TM-3001	"IRAC Detector FY87 Tasks and Tradeoff Study"	
	R. Taylor	11 September 1986
TM-3002	"Application of PV InSb for SIRTF Band 1"	
	R. Thom	17 October 1984
TM-3003	"Pixel Sizes"	
	S. Willner	28 November 1984
TM-3004	"Best Filters"	
	S. Willner	6 December 1984
TM-3005a	"IRAC Pixel Sizes and Super-Resolution"	
	R. Tresch-Fienberg	6 December 1984
TM-3005b	"More about IRAC Pixel Sizes"	
	R. Tresch-Fienberg	7 December 1984
TM-3006	"SIRTF Detector Requirements - Ver. X.1"	
	F. Low	20 March 1985
TM-3007	"IRAC and MIPS Detector Charts and Issues"	
	C. Leidich	9 May 1985
TM-3008	"Array Detector Subsystem Critical Issues"	
		not dated
TM-3009	"IRAC Detector Test Program"	
	G. Lamb	June 1986
TM-3010	"Size of IRAC Detector Cold Electronics Package"	
	R. Taylor	5 September 1986

13.0 IRAC/TM 4000-4999 Optical System Technical Memos

TM-4001	"Possible Modifications to IRAC"	
	S. Willner	29 October 1984
TM-4002a	"Short Wavelength Limit for SIRTF"	
	S. Willner	29 October 1984
TM-4002b	"Short Wavelength Limit to SIRTF"	
	S. Willner	8 November 1984
TM-4003a	"Bright Sources"	
	S. Willner	1 November 1984

TM-4003b	"Results of IRAC Observations of Planets" G. Fazio	13 November 1984
TM-4004	"Beam Splitters" S. Willner	28 November 1984
TM-4005	"CVF Limits" S. Willner	28 November 1984
TM-4006	"Dewar Optics Specifications for February Observing Run" D. Gezari	29 November 1984
TM-4007	"OCLI Paper about CVF's" R. Tresch-Fienberg	6 December 1984
TM-4008	"Application of STRAY to the Spacelab 2 Infrared Telescope" A. Dinger	20 August 1985
TM-4009	"IRAC Optical Design Update (Initial)" P. Maymon	6 January 1986
TM-4010	"IRAC Optical Design Update #2" P. Maymon	10 March 1986
TM-4011	"IRAC Optical Design Update #3" P. Maymon	31 March 1986
TM-4012	"IRAC Optical Design Phase 1 Proposal" P. Maymon, J. Mangus	30 June 1986
TM-4013	"IRAC Optical Design Update #4" P. Maymon	5 August 1986
TM-4014	"IRAC Optical Design Update" P. Maymon	21 August 1986
TM-4015	"Three-Mirror IRAC Design - Detector Clearance" P. Maymon	18 September 1986

14.0 IRAC/TM 5000-5999 Thermal And Mechanical Technical Memos**15.0 IRAC/TM 6000-6999 Electronics System Technical Memos**

16.0 IRAC/TM 7000-7999 Ground Support Equipment Technical Memos

17.0 IRAC/TM 8000-8999 Data Reduction And Analysis Technical Memos

18.0 IRAC/TM 9000-9999 Mission Operations Technical Memos

TM-9001	"IRAC Reference Mission"	
	Willner, Koch, Melnick	22 March 1985
TM-9002	"Science Operations Center"	
	S. Willner	21 August 1985